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Geology of Flagstones in the Endless Mountains Region, Northern Pennsylvania

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Geology of Flagstones in the Endless Mountains Region, Northern Pennsylvania

by J. Douglas Glaeser
Pennsylvania Geological Survey

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PREFACE

Natural resources constitute a major factor in the development and economic growth of any area. The Endless Mountains region of northern Pennsylvania has a variety of natural resources. This publication is intended to help define the nature and occurrence of one such natural resource of that area, namely flagstone, and has been prepared especially for individuals without geologic training who are interested in the discovery and development of flagstone deposits.

Flagstone is a mineral commodity which has been growing in use, being utilized in both domestic and industrial construction. Flagstone has certain specific properties, has been formed under distinctive geologic conditions, and is found within certain limited areas. By defining the properties, origin, and occurrences of flagstones in the Endless Mountains area, it is believed that mineral development as well as the overall economy of the region will benefit.

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GEOLOGY OF FLAGSTONES IN THE ENDLESS MOUNTAINS REGION, NORTHERN PENNSYLVANIA

By

J. Douglas Glaeser

INTRODUCTION AND PURPOSE

This is a report on the physical properties, regional distribution, occurrence, and origin of flagstones in northern Pennsylvania with emphasis upon methods for economic recovery. Flagstones have been produced commercially in the Endless Mountains region of northern Pennsylvania for more than a century. This region is comprised of Susquehanna, Bradford, Tioga, Sullivan, and Wyoming Counties (Fig. 1). As an industry, flagstone quarrying has remained largely a secondary income source for a majority of operators and for the most part has remained a marginal industry in the Endless Mountains region. In a relatively small number of cases, mechanized quarrying techniques have resulted in profitable business ventures. Nearly all operations have begun on relatively little information about the size, shape, extent, and quality of the flagstone prior to quarrying, and thus considerable expense is wasted on superficially good prospects.

It is the purpose of this report to show that size, shape, extent, and quality can be largely determined prior to the opening of a prospective flagstone operation, that new operations can be developed based on knowledge gained from existing quarries, and that production can be increased in some quarries now in operation and revived in many now abandoned. The extent and availability (reserves) of flagstone in the Endless Mountains region is for all practical purposes unlimited. This report does not consider demand for this apparently unlimited supply and assumes that the producers of flagstone can develop and expand markets.

GEOLOGIC PROPERTIES OF FLAGSTONES

What are flagstones? Flagstones are sandstones of relatively uniform grain size having characteristically uniform splitting properties parallel to their planes of stratification. Hardness, color, and resistance to weathering are controlled by mineral composition of the sandstones. Colors are commonly bluish or greenish grays, although some are red or reddish gray.

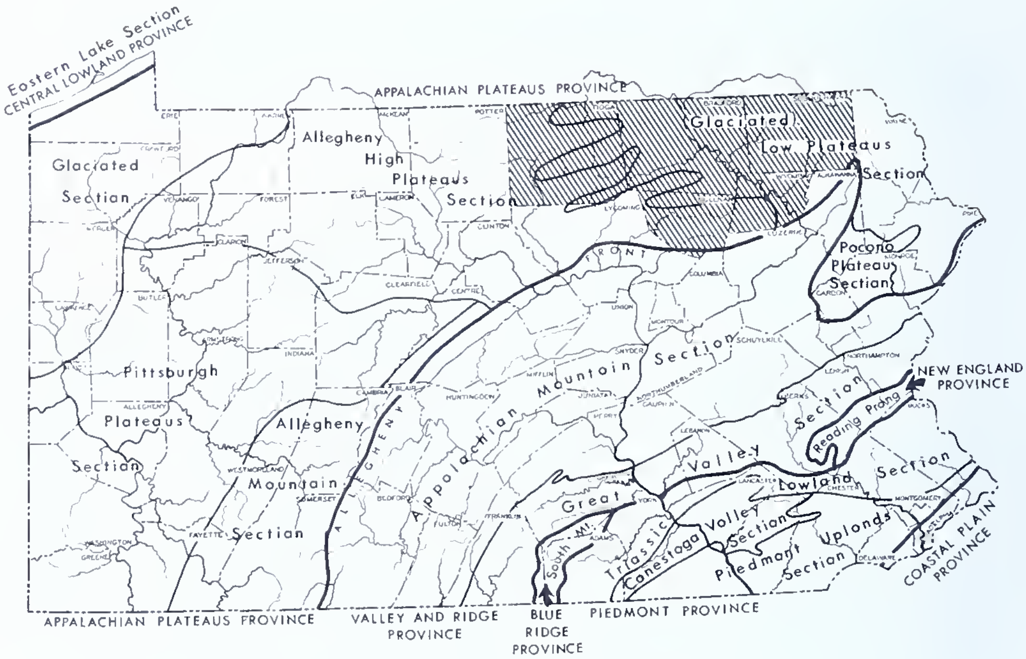


Figure 1. Location map of report area.

Surfaces of splitting are flat and smooth with characteristically constant thickness between the top and bottom surfaces of any flagstone regardless of its overall dimensions (Fig. 2). This ability to split into parallel-sided slabs is a result of one of the most fundamental properties of flagstones: namely, parallel stratification, or where stratification is very thin, parallel lamination. Parallel stratification results from the presence of alternate layers of light and dark minerals in the rock or from the presence of very thin shale layers or partings between the relatively thick, uniform sandstone layers. The interlayering producing parallel stratification most commonly occurs in sandstones which were deposited by rapidly moving water currents. Such currents commonly occur in streams or along coastlines.

Because this most important feature, parallel stratification, is a result of a fundamental geologic process, the successful location of potential flagstone is governed primarily by recognizing the geologic conditions of origin of the rocks at the prospective site of the quarrying operation. The future development of a profitable flagstone industry in the Endless Mountains region is largely dependent upon using primary features visible in the rocks in determining the size, shape, extent, and quality of a potential flagstone unit. These properties can be expressed on maps, interpreted from bore holes and determined from obvious physical features which the quarry operator can observe and use in developing and expanding the quarry operation.

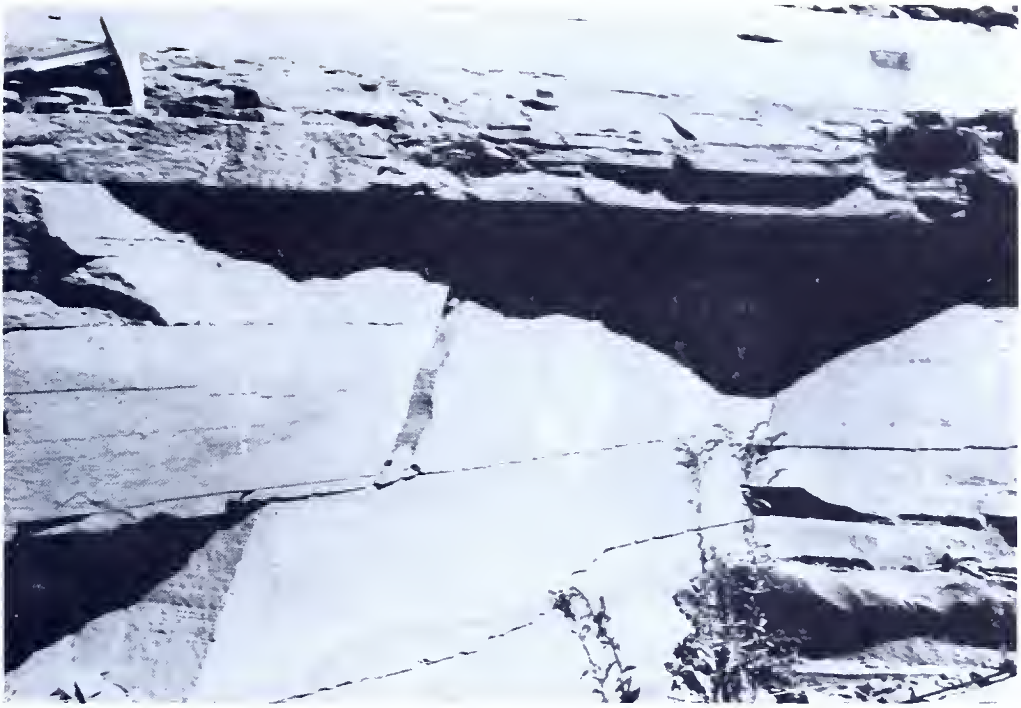


Figure 2. Quarry face showing distinctive, natural-splitting properties resulting from parallel stratification in flagstones. Note geologic hammer for scale.

AREAL DISTRIBUTION OF ROCKS CONTAINING POTENTIAL FLAGSTONES

Where in the Endless Mountains region do flagstones occur? Rock strata in which potential flagstone occurs are outlined in a general way in Figure 3. The map also shows areas which are not probable source areas of flagstone. The reserves in the region of potential flagstone occurrence are thought to be sufficiently large that prospecting efforts should be concentrated there for the most reasonable chances of recovery at the present time.

Detailed geologic mapping, within the region on the map (Fig. 3) shown as good areas for potential flagstone prospecting, indicates the presence of two distinct formations of stratified rock which look different in outcrop. However, both formations contain the types of sandstones which should be considered for their flagstone potential.

The first formation consists of bluish and greenish-gray sandstones alternating with red sandstone, siltstone, and shale. Because of this

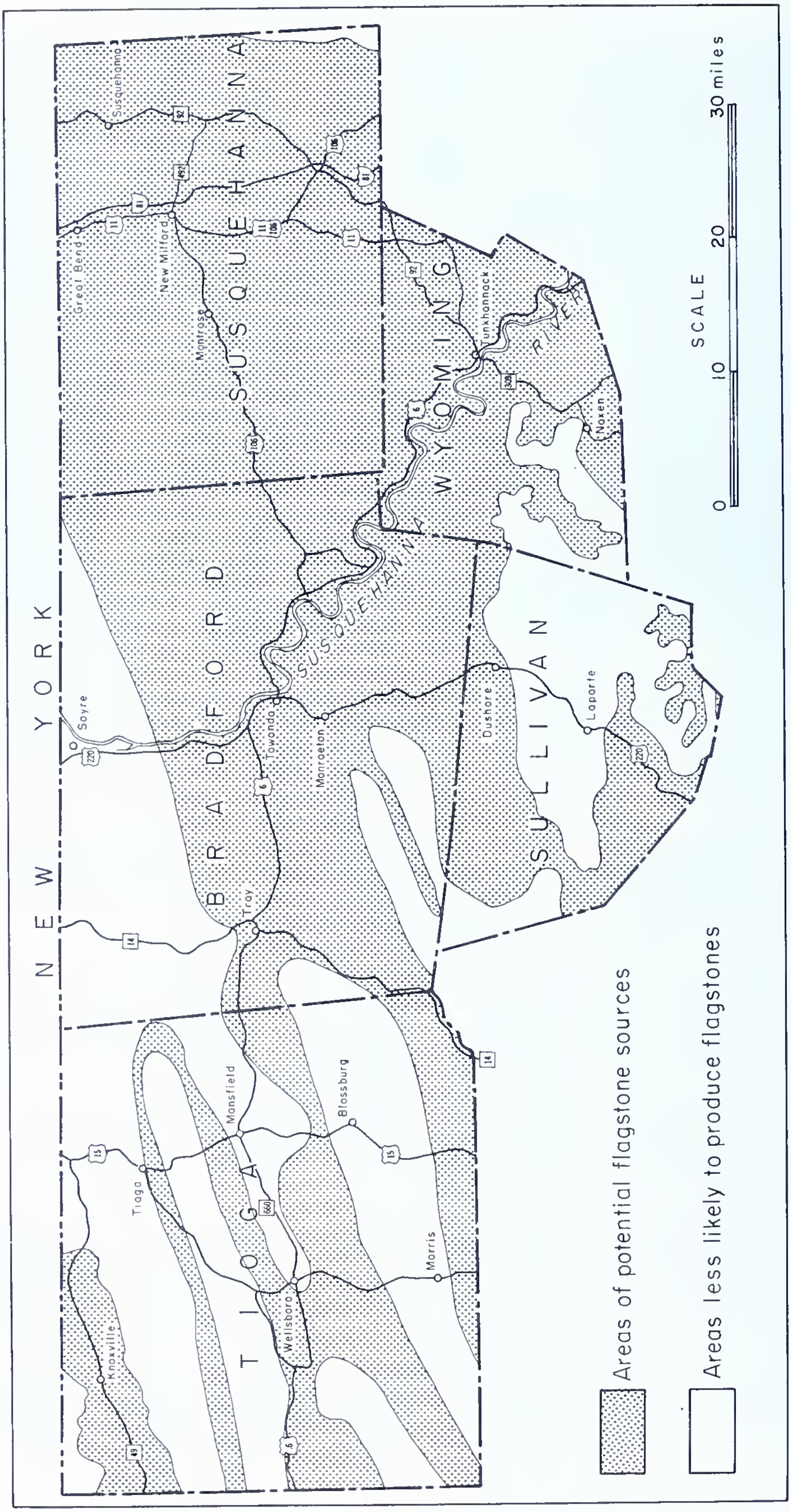


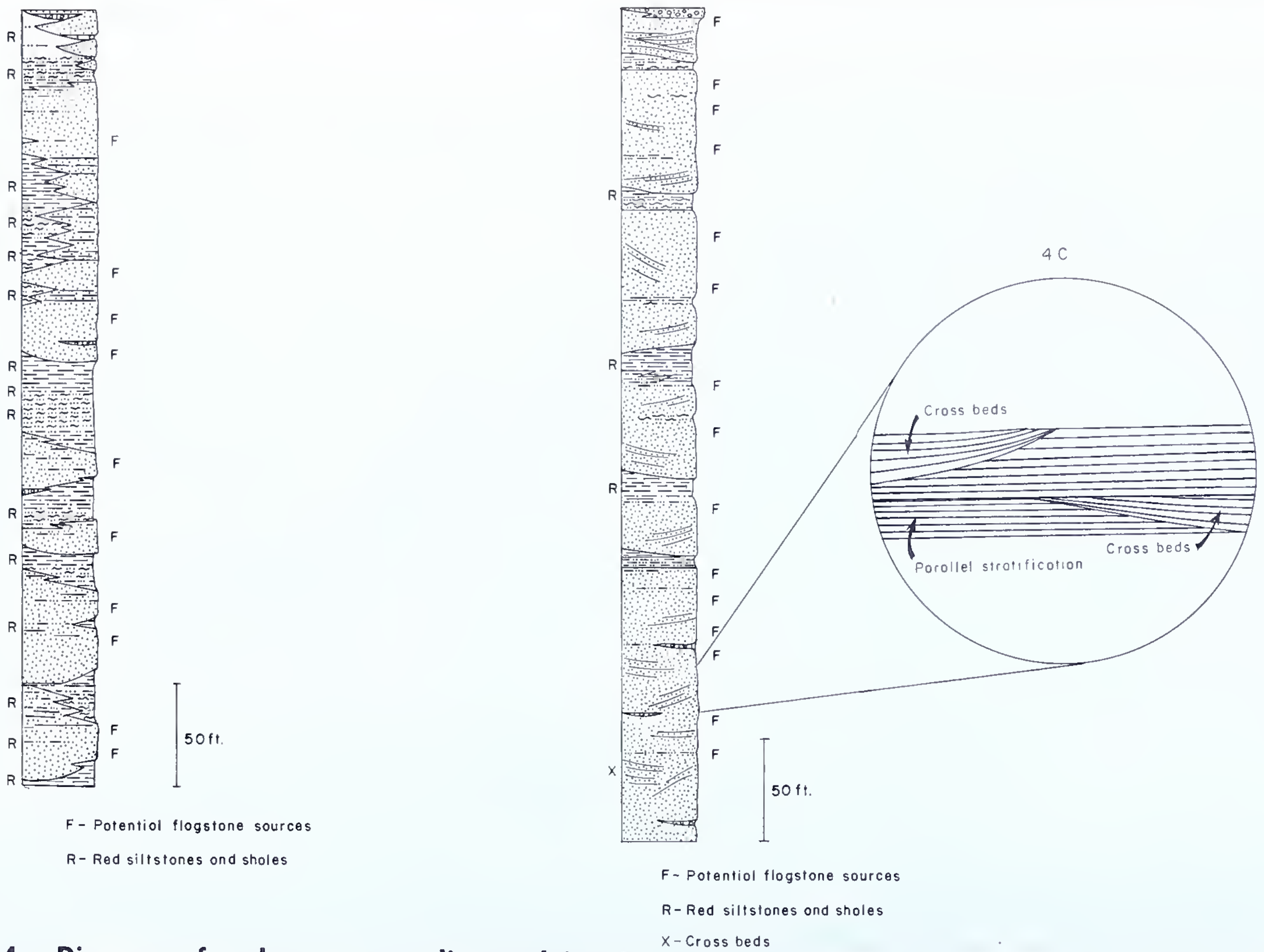
Figure 3. Map showing potential distribution of flagstone in the Endless Mountains region.

alternation of strata, the gray sandstone beds, which are the best potential source of flagstone, repeat many times upward along slopes of the hills. The thickness of the gray flagstone-producing sandstone in each of the alternations generally ranges in thickness from 4 to 30 feet. The red rock between the individual sandstone beds usually is 2 to 30 feet thick. Thus, in most locations, there is rarely more than 30 feet of waste rock vertically separating potential flagstone beds.

Because each of the gray sandstone beds is bounded at its top and bottom by red rock, many quarry operations have been abandoned when the bottom of a good flagstone bed is reached. Bore holes in the quarry floor can be used to determine the depth at which the next sandstone occurs beneath the present quarry floor. Where the red rock or other poor quality stone is sufficiently thin to justify excavation, quarrying can proceed at the same site at a deeper level once the physical properties indicating potential flagstone in the bore hole have been determined.

Figure 4A is a schematic diagram of the alternating strata of gray and red rock. The positions in this vertical section of rock where flagstone most frequently occurs are also shown in Figure 4A. The diagram is not based on an actual example but is presented here as a guide to show how the strata typically alternate in most parts of this formation.

The second formation, which warrants detailed investigation in prospecting for flagstones, is made up mainly of sandstones commonly without the alternating strata of red rocks. In the eastern part of the region, it is similar in its alternations to the first formation described, although the sandstone units are thicker in this second formation. Although there is more sandstone present everywhere in this formation, it is not made up entirely of potential flagstone. The sandstones present in many places contain strata which are inclined at various angles within any particular exposure of the rock. These beds which dip more steeply than the surrounding strata are called "crossbeds". Crossbeds in this formation commonly look like flagstones, but often their thickness is not uniform, and their size and shape limit their value as good quality flagstone. However, these crossbeds are frequently found at the sides of or just above thick massive sandstones having parallel stratification which is a principal requirement in producing flagstone. Such sandstone beds of potential flagstone quality can be distinguished in core borings because the parallel stratification planes have a lower angle of dip than do the crossbeds. A diagram (Figure 4B) shows the general appearance of a hypothetical rock section in this second formation, and the position of potential flagstone sources is shown in relation to the cross-bedded sandstones (Figure 4C).



4 C
Cross beds
Parallel stratification
Cross beds
50 ft.
F - Potential flagstone sources
R - Red siltstones and shales
50 ft.
F - Potential flagstone sources
R - Red siltstones and shales
X - Cross beds

Figure 4. Diagram of rock sequences discussed in report that are typical of formations in which flagstones commonly occur.

GEOLOGIC DATA USEFUL IN LOCATING POTENTIAL FLAGSTONE SOURCES

The bedrock in certain parts of the Endless Mountains region has been mapped in detail. All published geologic information concerning the bedrock in this area is listed in the references.

Heretofore, finding a potential flagstone quarry has been based on fortuitous location of a hillslope or hilltop ledge of outcropping sandstone or actual flagstone. Only after removal of vegetation and overburden, followed by initiation of quarrying, was there any indication that flagstone in commercial quantities might be available. Use of the distribution map (Figure 3) coupled with more detailed geologic data where available is the first step in locating a potential source of flagstone.

The second important step is observation of terrain and topography in potential flagstone areas. The Endless Mountains region is an area characterized by relatively wide, flat valleys with steep hills and mountains rising abruptly from the valley margins. The broad, flat nature of the valleys suggests that they are dominantly filled by sand and gravel deposits (of potential economic value) and are not likely areas in which to prospect for flagstones. The mountains are moundlike, gently rounded, and relatively broad and flat. The rock formations which cause the mountains to stand in relief above the flat valley floors are made up of very gently inclined (dipping) strata, some of which are potential source beds of flagstone. Similar strata may occur in neighboring mountains, and thus a knowledge of the angle of inclination of sandstone strata is of major value in projecting the position of a flagstone bed from one hillslope to another (Figure 5). Also where hilltops are flat, this suggests that sandstone beds are probably just beneath the soil. Where hillside benches or steplike ledges occur, this also indicates the presence of

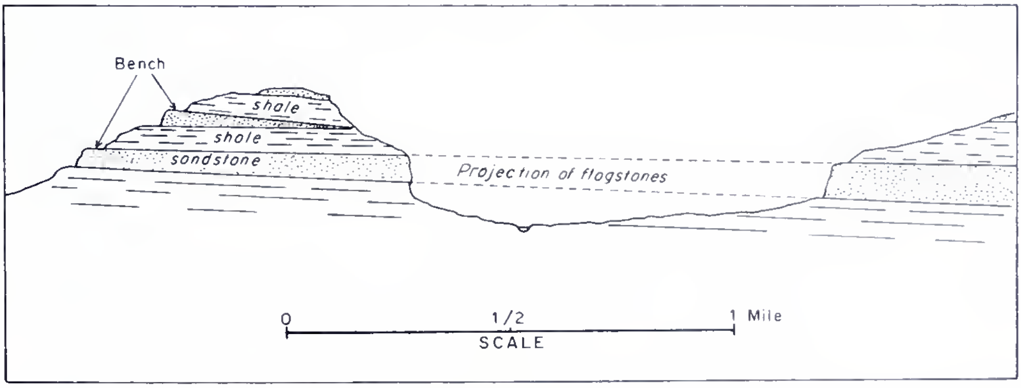


Figure 5. Cross section of hills containing flagstone strata showing means of projecting units.

massive sandstone beds of flagstone potential (Figure 5). The remaining steps in locating prospective flagstone quarry sites, listed below, can best be carried out with the guidance of a consulting geologist.

1. Selection of a site or sites within the limits of property rights where sandstone bedrock is locally exposed and where the soil on slopes or hilltops is not predominantly red.

2. Core boring on a grid of coring sites with spacing sufficiently close (25 to 50 foot centers) to determine the size, extent, and thickness of sandstone units. After penetrating the soil and gravel with the coring device, drilling should proceed through at least one non-red sandstone body until red rock or shale is encountered. The areal extent and thickness of the sandstone unit then can be used to compute the volume of sandstone available.

3. Analysis of cores to find well-sorted sandstones, having parallel stratification planes, and an absence of thick shale beds intermixed laterally or vertically with the sandstone.

4. Compositional analysis of thin sections from cores can be used to compare mineral composition of the sandstone with those from flagstones of known quality.

GEOLOGIC DATA USEFUL IN EXPANDING A FLAGSTONE OPERATION

In all quarries examined in this study, it was apparent that operators have taken advantage of the presence and spacing of vertical jointing in the bedrock (Fig. 6). The preponderance of joints examined are oriented nearly north-south and east-west. Sketches of five active quarries in which it is apparent that working faces are natural vertical joint surfaces in the rocks are shown in Figure 7. A rose diagram in Figure 7 shows joint-surface orientations. At present, all quarry expansion appears to follow joint directions. However, there need be no relationship between the longest dimension of the flagstone body and the orientation of joint surfaces. Thus joint surfaces can be used to aid in opening new faces and zones within a flagstone body being quarried, but other primary features of the rock should be used to determine direction of expansion where flagstone appears to be running out.

It is inevitable that as active quarrying proceeds, quality flagstone will run out. That is, the flagstone bed or beds will pinch out into one of the sides of the quarry, into the working face or in the working surface of the quarry floor. When good flagstone runs out in one of these directions, can the direction of quarrying be shifted and how is the direction of shift determined?

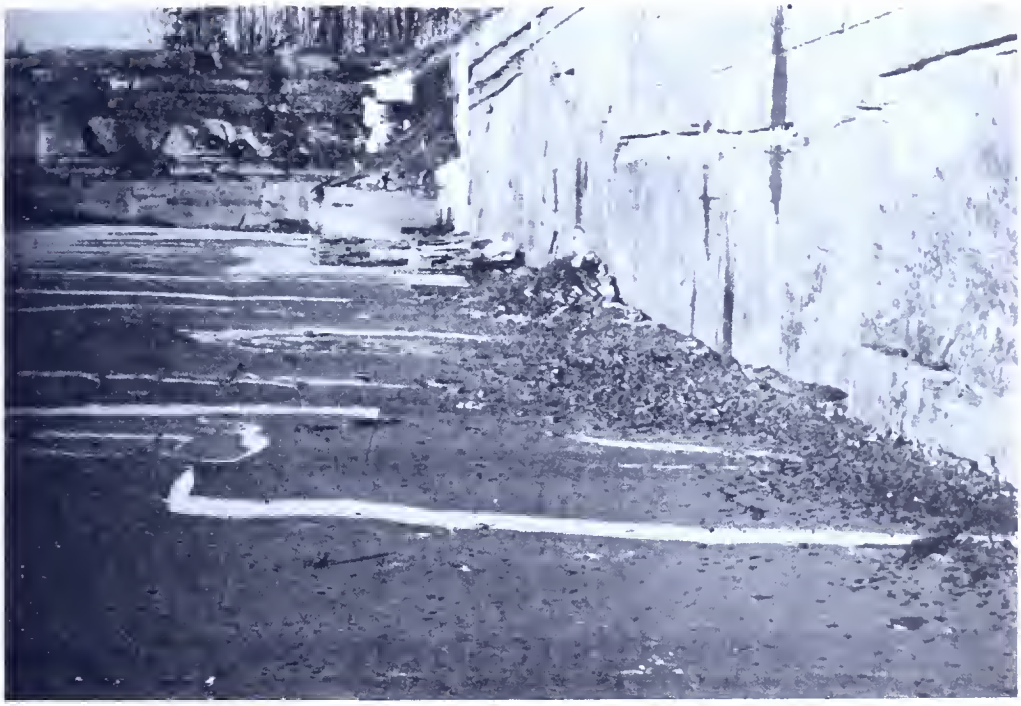


Figure 6. Vertical quarry walls with natural joint surfaces. View is toward the north showing the well-developed, north-south and east-west vertical joint sets which are used as natural working faces.

Where good flagstone runs out in the quarry floor, core drilling can be used to determine depth to the next deeper sandstone unit having properties, previously described, of potential flagstone. Amount of waste rock can thus be computed before an investment is made in its removal. Where this amount exceeds economic feasibility of removal, quarrying may proceed laterally or into the working face.

Core drilling again can be used to determine the direction in which to quarry. Drilling should be carried out along the long dimension of the sandstone body. An observable feature of the flagstone itself can be used by the quarry operator to determine the long dimension of the flagstone body. This feature is called "ties" by the quarrymen and "parting lineations" (or "current lineations") by geologists (Fig. 8). Parting lineations are ribbonlike ridges of irregular width on the scale of several inches wide which stand slightly above the normally smooth surface of the stone. They are formed by water currents, and their long dimension defines the path of current movement. They form up and down the slope of a beach by the back and forth motion of waves. In streams, parting lineations parallel the direction of flow. Thus where a flagstone deposit is of beach origin, the parting lineations form perpen-

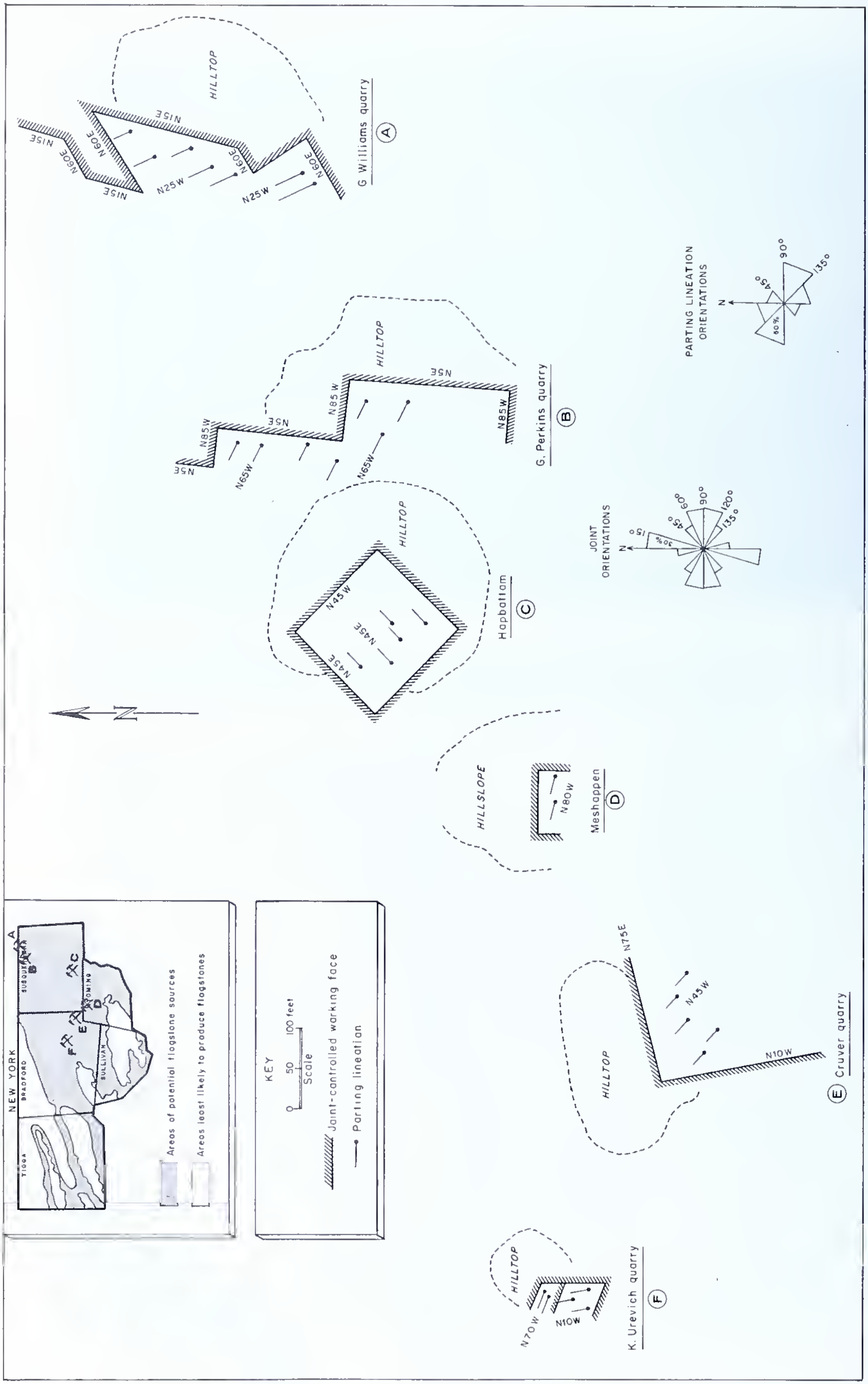


Figure 7. Areal sketch of some active flagstone quarries showing orientations of joints and parting lineations.

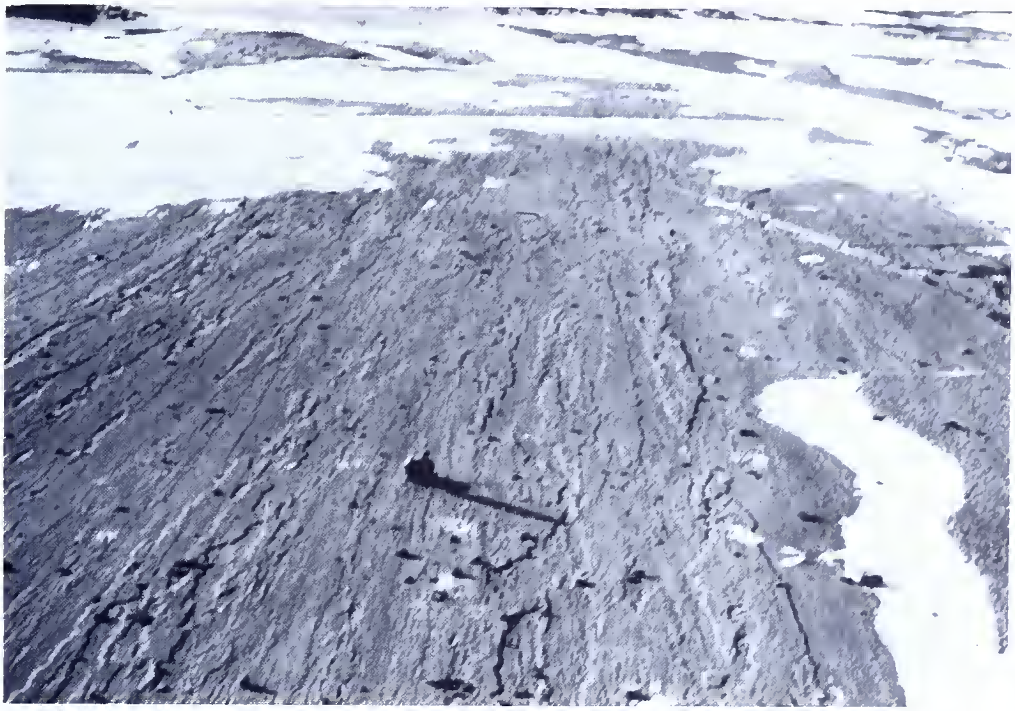


Figure 8. **Parting lineations (ties) on bedding surface of quarry floor. Parting lineations are aligned in the same direction on any single bed surface and usually have a common orientation within a single flagstone deposit. Note compass in foreground for scale.**

dicular to the shoreline and thus lie in the direction opposite the long dimension of the beach deposit. Flagstone deposits of stream origin have parting lineations parallel to the long dimension of the deposit.

Geologists use many criteria for distinguishing beach from stream deposits. The following are some criteria which can be used in the field.

1. Beach deposited sandstones usually are well sorted.
2. They show less interbedding with shale and other rock types than do stream deposited sandstones.
3. Sandstones of beach origin have bimodal cross-bed orientations, whereas stream deposited sandstones show cross-bed orientations generally in the direction of flow (that is, unimodal).
4. Parallel stratification in beach deposits extends for very large distances parallel to the long dimension of the beach and thins out more rapidly perpendicular to the long dimension.
5. Presence of fossils indicating marine conditions is most helpful in distinguishing beach from stream deposits, although fossils are not common in the flagstones of northern Pennsylvania.

The flagstones examined in active quarries shown in Figure 7 are all thought to be of beach origin although potential flagstone sites within the region may be of stream origin. Thus, expansion of quarries shown in Figure 7 would take place in the long dimension of the flagstone body which in these cases is predicted to lie perpendicular to the parting lineations shown on each sketch of the quarries. The determination of origin (beach or stream) should be made at the individual prospective quarry site prior to using parting lineations as a guide to determining the long dimension of the sandstone body.

Measurements of parting lineations were made on many exposed beds in each of the active quarries shown in Figure 7. With the exception of one location, all parting lineations are rigorously parallel to one another on all bedding planes exposed within any single flagstone body. This persistence in orientation at any one site supports the current origin of parting lineations in these flagstone bodies. Apparently, any single flagstone body is a result of sand build-up at one site over a relatively extended period of time and under the influence of currents having uniform flow directions. The rose diagram of parting lineation orientations in Figure 7 shows that these currents were dominantly northwest-southeast oriented during deposition of the sandstones.

The above data suggest, therefore, that an apparently "depleted" operation may continue to develop within the limits of property rights rather than resulting in closing the operation and searching for new sites. Obviously, some operations will have exposed and removed the available sandstone from the quarries, and economic factors of further expansion dictate how far from the quarry surface it is feasible to prospect.

GEOLOGIC FACTORS OF FLAGSTONE QUALITY

Until mineral composition standards for flagstone quality are established, four qualitative factors can be used as guides to determine the usefulness of sandstone for flagstone in the Endless Mountains region.

1. Presence of parallel stratification. This property and its significance have been discussed earlier in this report.

2. Grain size. Good flagstones are composed almost entirely of sand-size fragments, and generally the sizes in any particular bed are restricted to one of the following size ranges: very fine sand (1/16 to 1/8 mm), fine sand (1/8 to 1/4 mm), and medium sand (1/4 to 1/2 mm).

3. Sorting. Range of sand-grain sizes is an important control on quality and is inherently related to the origin of parallel stratification.

Good quality flagstone has a restricted range of sand-size fragments, and rarely does flagstone have a wide range of sand-size fragments or high amounts of material finer than sand size, such as clay.

4. Color. Flagstone color is an indication of mineral composition which affects its ability to withstand weathering. Although any color flagstone may attract a market, red or reddish gray flagstones are more easily weathered and thus less resistant than are the various shades of bluish and greenish grays. Red flagstone contains hematite and usually a higher amount of clay-size material than does the gray flagstone. In addition, the presence of hematite and clay in the red flagstone of this region generally indicates that lesser amounts of silica cements are present than are found in the tougher and more weather-resistant gray flagstones.

CONSERVATION

In stimulating any industry which extracts material from the earth, organized groups of citizens who are encouraging such development must have a prime concern for the long range effects such extraction has upon the region. Two factors are of special importance in the Endless Mountains region.

First, quarrying can have detrimental effects upon the landscape of the region. Because the magnificent countryside of the Endless Mountains region may be its most important economic asset, quarry operators must be guided and encouraged in their methods of dumping and storage of waste rock and in restoring a completed operation to a more natural setting.

Second, large quarry operations may affect the ground water in surrounding areas. Where quarries intersect the ground-water table, measures are required to restore the water to the surrounding area without contaminating it or flushing it away into a stream downslope.

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